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SCIENCE-BASED ANIMAL WASTE PHOSPHORUS MANAGEMENT FOR OKLAHOMA

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Executive Summary
Poultry and swine production has created both economic growth in Oklahoma and concern over the effect of excessive land application of animal manure on water quality. Along with economic benefits, producers are faced with disposal of large amounts of animal manure generated from poultry and swine production. Land application of animal manure increases soil P and has raised concerns about P runoff from agricultural land and environmental degradation of streams and lakes.

Several states have proposed standards that would limit manure applications and avoid excessive levels of soil P and reduce impact of P on water quality. Standards may be based on *nutrient utilization* where manure is applied to meet P required for crop production. Standards based on *waste disposal* exceed nutrient P crop requirement and allow for some buildup of soil P.

Several decades of scientific research has documented the relationship between soil P index, crop production, and water quality. Application of manures to soil at P levels required to produce crops minimizes impact on water quality. Science-based fertilizer recommendations used by Oklahoma State University, based on decades of field and laboratory research, show a soil test value of 65 is adequate for production of most crops. Recent research by soil scientists at Oklahoma State University shows that a field-average soil test of 120 can be used to ensure most areas of a field have sufficient P with soil test levels of 65+ and prevent any localized deficiencies due to soil variability. Therefore, *nutrient utilization* standards require that animal manure applications do not result in soil test levels that exceed 120. This will ensure adequate levels of P for crop production and minimize impact on water quality in Oklahoma. Adequate scientific information needed to set risk-based waste utilization standards for Oklahoma is not available at present.

Introduction.
Management of animal waste in Oklahoma has gained interest in recent years as a result of rapid increases in confined-animal waste production. Whether animal waste is considered a resource or not, depends on how it is managed and whether it can be beneficially utilized or is simply disposed of without benefit. Historically, animal wastes have been land-applied to agricultural fields as a beneficial input to crop production. Increased soil organic matter and increased plant available nutrients are recognized as the major benefits. Increasing soil organic matter changes several soil properties, directly and indirectly related to crop production. Therefore, the effect of increasing soil organic matter on crop production has been difficult to quantify. However, the relationship between increasing soil availability of plant nutrients and benefit to crop production has been a subject of widespread scientific inquiry for decades and is well documented. In the scientific processes of improving the understanding of soil availability of plant nutrients and crop response, much has been learned about the fundamental behavior of plant nutrients in the soil. This knowledge also provides a foundation for understanding how soil applied plant nutrients, from any source, might influence the environment.

General Soil-Nutrient Relationships.
The chemical and biological (soil microorganisms) activity of nitrogen (N), phosphorus (P), and potassium (K) in soils causes plant available N to move in the soil in response to water movement, while P and K do not, at concentrations required for

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optimum plant growth. Soil immobility of P is a result of orthophosphate precipitation by calcium (Ca) in soils above about pH 5.5 and precipitation by aluminum (Al) and iron (Fe) below about pH 5.5. Nitrogen is mobile because most N is plant-absorbed as the non-precipitating nitrate (NO_3) form, the final oxidation state of organic- and ammonium (NH_4)- N. Consequently, N management for crop production is directly related to crop yield because the total inorganic N present can support plant growth. Management of available P and K is not directly related to crop yield because plants can only extract these immobile nutrients from a thin layer of soil surrounding the root. The total amount of inorganic P and K present is not as important as the concentration of these elements in the soil next to the root surface and the capacity of that soil to replenish P and K in the soil solution when it is removed by plant uptake. Soil tests have been developed to provide an index (Table 1) of the soil capacity to supply adequate amounts of these nutrients during the crop growing season. In addition to identifying the soil-P condition where deficiency is likely to exist (soil test index < 65), scientists also calibrated the soil test to identify probable yield (% sufficiency) when the deficiency exists, and the amount of fertilizer P_2O_5 required annually to correct the deficiency. The soil test P index (STP) is produced using the Mehlich III (M III) extraction procedure in Oklahoma. This method has gradually become a widely adopted technique for estimating plant available P.

Table 1. Calibration of Mehlich-III soil test P for wheat grain in Oklahoma.

P Soil Test Index*	Percent Sufficiency	P_2O_5 (lb/acre)**
0	25	80
10	45	60
20	80	40
40	90	20
65+	100	0

* Value is pp2m soil basis (same as lb/acre numerically).
** Fertilizer input.

Crop Response To Fertilizer-P.
Soil test calibrations, such as Table 1, were developed for Oklahoma and most of the other states more than 20 years ago and involved replicated fertilizer rate experiments on farmers' fields over broad geographic regions. Findings were similar, and current soil test calibrations do not differ markedly from one state to another when similar testing procedures and reporting units are used. Use of soil testing to identify deficiencies and continued annual application of fertilizer-P results in enrichment of plant-available soil-P. A long-term research experiment at the OSU Agricultural Experiment Station at Lahoma, Oklahoma documents the effect of soil-P depletion and enrichment from 27 years of annually applying 0 to 80 lb/acre fertilizer-P for annual winter wheat production (Figure 1). This research also documents the lack of wheat yield response to STP values above 65 (Figure 2).

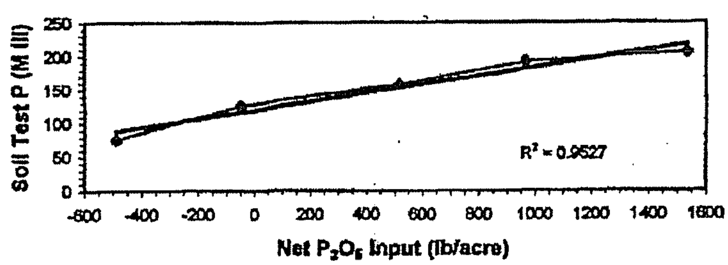

Figure 1. Change in soil test P (pp2m) resulting from 27 years of fertilizer-P input and wheat grain removal (Lahoma 502).

From Figure 1 it can be calculated that a net change of about 15 lb P_2O_5/acre is required to raise (fertilizer-P input) or lower (crop-P removal) the soil test P by a value of 1.0 for this Grant silt loam soil.

It is possible to increase STP by simply adding P fertilizer, but Figure 2 shows higher yields do not result from P application when STP is greater than 65.

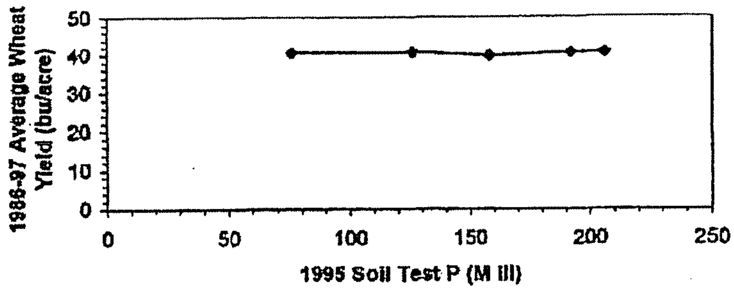

Figure 2. Lack of wheat grain response to soil test P values above 65.

Crops do respond, although slight, to relatively large inputs of fertilizer-P when soil tests are less than 65 as illustrated by Figure 3, showing alfalfa yields in relation to fertilizer-P in a current research study at the OSU Agricultural Experiment Station at Chickasha, Oklahoma. The initial soil test P level averaged about 30, but was quite variable for the site in 1992.

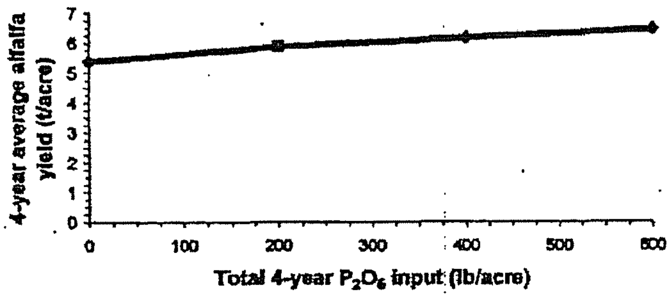

Figure 3. Alfalfa yield response to high rates of fertilizer-P in a P deficient soil (STP = 30) at Chickasha, Oklahoma.

Field Variability.
Recent research, evaluating soil test variability within fields, has identified that portions of a field should respond to fertilizer-P even when the composite soil test for the field is greater than 65. This results from the composite sample, composed of 12 to 15 core samples (0 to 6 inch depth), containing soil from some areas of the field that would be higher than 65 and some areas lower than 65. In order to obtain maximum yield for the entire field it would be necessary to fertilize the field even after the composite sample STP was 65. The STP value, for a composite sample from a variable field may need to be almost double the value of 65 to ensure all P-deficient areas of the field received enough fertilizer P to eliminate P deficiency in the field (Figure 4).

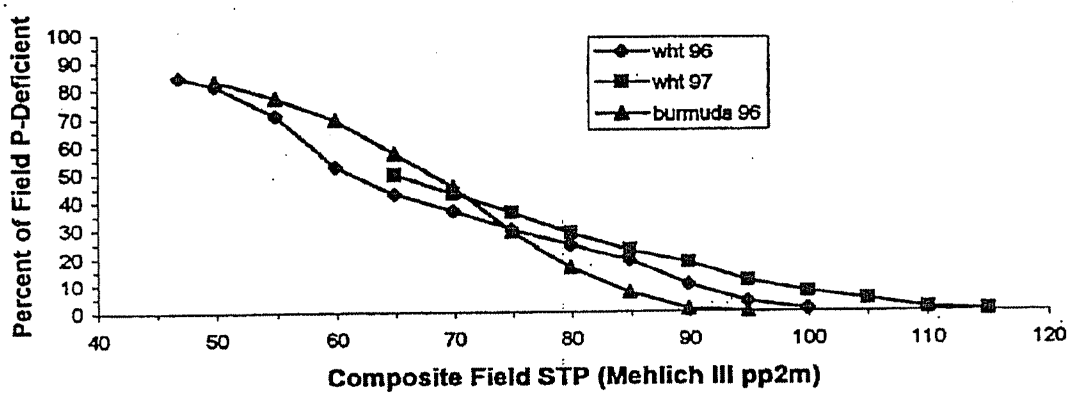

Figure 4. Projected percent of field that would be P-deficient when soil test P value is from a composite for a normally variable field. Field variability estimated from soil testing 250 to 500 areas of each field.

As the soil test P value from a composite field sample increases above 65 the amount of response to fertilizer P addition decreases and the effect of excess P increases when a constant rate of P is applied to the entire field.

Effect of Excess Soil-P.
One of the effects of increasing soil test P is that soil solution P also increases. This has been documented in the past as scientists evaluated forms of soil-P in relation to fertilizer addition and plant response. Recent analysis of samples, selected to represent a broad range of soil test P values for soils submitted to the OSU Soil, Water, and Forage Analytical Laboratory for routine analysis, showed the relationship existed over a wide range of soil test P (Figure 5). The calculated water soluble P at a soil test P value of 65 (regression equation, Figure 5) would be 0.057 ppm P, which is consistent with published values identifying the water soluble P level to support crop needs (Tisdale et al., 1993, p 180).

Since the concentration of water soluble P in soils increases as soil test P increases, it is reasonable to expect the risk to water quality from soluble P will also increase when soil test P increases. Manure application standards based on soil test P levels that exceed crop production needs have been proposed or adopted in several states.

Table 2. Critical levels of soil test P proposed to protect water quality from excessive levels of soil P buildup from manure application.

State	Soil Test Critical Value
Arkansas	150 mg kg^{-1} Mehlich 3 P
Delaware	120 mg kg^{-1} Mehlich 1 P
Michigan	75 mg kg^{-1} Bray 1 P
Ohio	150 mg kg^{-1} Bray 1 P
Oklahoma	130 mg kg^{-1} Mehlich 3 P
Texas	200 mg kg^{-1} Mehlich 3 P
Wisconsin	75 mg kg^{-1} Bray 1 P

Agreement between states on universal soil test critical levels has not been reached for several reasons. Some degree of environmental impact is likely from soils with test P that exceeds crop production levels. However, there is little scientific information that relates soil test P to a known environmental impact. Furthermore, a universal soil test critical level may not have any scientific basis because the environmental impact from soil test P will be watershed dependent. Use of soil test levels that exceed crop production levels require risk-based decisions. However, little data is available to support risk-based standards (Sharpley et al., 1996).

Management of Soil-P Inputs: Utilization vs disposal.
When management of P inputs to soils are considered, two clear outcomes are of concern with any strategy. First there is the traditional management of P inputs to improve crop production

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related to the needs for food and feed. Input rates are usually small because of economics when commercial fertilizer is used. Second, there is the recent concern to manage P inputs to minimize risk to surface water quality. Guidelines for P inputs related to crop production are clearly defined by scientific work. When soil test P values are below 65, inputs of fertilizer-P according to soil test calibration are prudent for increased crop production. When fields are known to be variable, crop yields may be further increased by inputs of P until the composite soil test P value reaches about 120. When the soil test P value exceeds 120, there is no longer a benefit to crop production from P addition to the field.

When P inputs, in the form of animal waste-P, are managed with the interest of balancing the benefits of food production against risk to the environment, a STP value of 120 clearly differentiates utilization from disposal. Addition of animal waste to fields testing below 120 involves utilizing the waste for beneficial purposes. Addition of animal waste to fields testing above 120 involves disposal of the waste without benefit to crop production, but with increased risk to water quality by runoff and/or erosion.

As a final consideration, management of P in the form of animal waste or commercial fertilizer should be sensitive to the fact that P comes from natural, nonrenewable reserves of finite size. Current known US reserves of rock phosphate for fertilizer manufacturing have been estimated to be depleted in about 25 years at the current rate of consumption. Unless new reserves are found, recycling of P through the food-feed chain will become increasingly important.

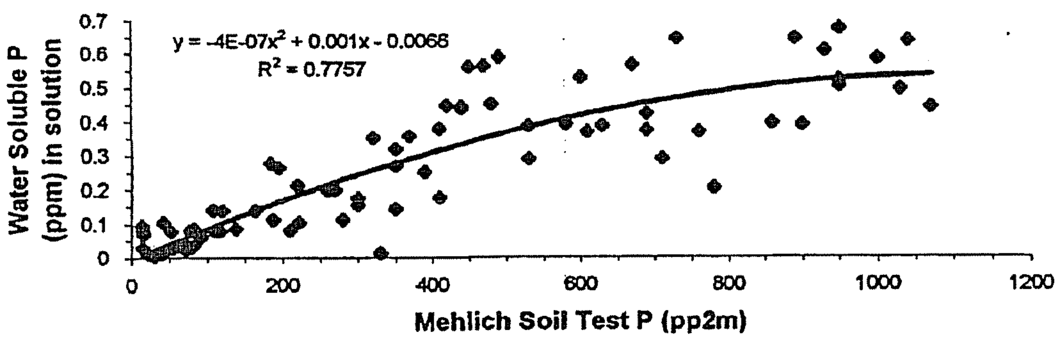

Figure 5. Relationship of soil test P and water soluble P (soil:solution ratio of 1:12.5) selected to represent a wide range of soil test values, from samples submitted to the OSU Soil, Water, and Forage Analytical Laboratory in 1997.

References.

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Tisdale, S.L., W.L. Nelson, J.D. Beaton, and J.L. Havlin. 1993. Soil fertility and fertilizers. Fifth ed. Macmillan Publishing Company, New York.

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